Potential Impact of Engineered Nanomaterials Release into Environment

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Abstract
Engineered nanomaterials (ENMs) are defined as a materials with at least one dimension between 1 nm to 100 nm. They have large surface area and specific electronic, optoelectronic, thermal and catalytic properties in comparison to their bulk counterparts, which make them particularly useful. ENMs that are found in different products (paints, cosmetics, medicines, food, sun tan lotions, remediation treatments, etc.) are usually designed to achieve desired properties. Those materials can be released into the environment throughout their entire life cycle and their extensive usage nowdays could led to their accumulation into environment. Over the last twenty years, ENMs have significantly increased in quantity produced, thus their presence in environment could have significant impact. However, understanding the effects that engineered nanomaterials (ENMs) have on environment through these applications is still limited. The aim of this paper is to point out issues releated to release of ENMs into the environment.

Key words: engineered nanomaterials, impact, environment, waste

Introduction
Technologies are constantly changing in a way to provide us a better life, but they also bring new risks. There is a tension between two things: power of science and its capability to avoid consequences, especially in the field of the environment.
The use of engineered nanomaterials (ENMs) has increased during the last years and this will continue in the future. Growth in the usage and development of ENMs has led to their uncontrolled release into different environmental mediums (water, air, soil). ENMs can be released to the environment throughout their entire life cycle [1] and base of that all phases in that process must be monitored.
However, the effects that ENMs have on environment are still not well studied and described. It is likely that, just as the ENMs have influenced science, they will potentially have some effects on environment. Also, these novel materials could pose new challenges to the current waste management strategies either by making them inappropriate or inadequate. The aim of this paper is to point out issues releated to release of ENMs into the environment.

Discussion
Engineered nanomaterials are identified as a material with at least one dimension between 1 nm to 100 nm. ENMs possess large surface area and they show specific properties (such as electronic, thermal, catalytic, etc.) in comparison to their bulk counterparts. Some of their properties (surface area, biological reactivity, size, durability, tendency to aggregate, hydrophobicity, etc.) may help bonding with different pollutants and facilitate their transport through air, soil and water [2]. ENMs are known to move with significant velocities through

aquifers and soils [3], and may act as carriers for fast transportation of pollutants throughout the environment. For example, polycyclic aromatic hydrocarbons (PAH) [4] can be adsorbed by carbon nanotubes causing an enhancement of the PAH toxicity, and in addition, ENMs have been shown to have affects on the fate, transformation, and transportation of chemical compounds in the environment [5].

ENMs that are found in commercially available products are usually modified in some way: surface and free ENMs are unlikely to be found. Their will most likely be a function of the product matrix and ENM surface characteristics.

The list of most commonly used ENMs consists of fullerenes (e.g., C60), single- and multi-walled carbon nanotubes (SWCNTs and MWCNTs, respectively), nanoclays, and nanoparticles of Ag, Au, TiO_2, CeO_2. Due to their properties they can be found in a variety of consumer products such as paints, cosmetics, medicines, food and sun tan lotions, as well as in different applications such as remediation of polluted environments [6]. These ENMs have increased in quantity and volume over the last decades, and their unrestrained release into the environment will probably grow in the following years and decades [7].

Numerous scientific studies have highlighted the influence on science nanomaterials have and exponential growth in nanotechnology [8] but they do not contain enough scientific data on feasible approaches of dealing with nanowaste streams generated at various phases of the nanotechnology-based products and materials life cycle. The insufficiency of scientific publications to address the waste management of nanowaste streams is sign of limited studies in this field and lack of enough verified impacts. However, nanowastes are potentially the most single pathway of introducing ENMs into the environmental systems and because of that this topic certainly deserves scientific attention and further detailed studies. Failure to address these concerns leaves continued uncontrolled release of ENMs into the different environmental mediums that may cause their contamination. In the future, this not only threatens water resources, but, may prove to be impossible to remediate because of: the size of the problems, clean up costs, and insuficiency of adequate technologies for remediation and monitoring tools to identify the contaminated areas.

For example, the cosmetics and personal care sector constitute the largest number of nanoproducts (more than 50%) currently available [9]. Over the last few years the use of ENMs in cosmetics and personal care products has increased for several reasons: ability to absorb and reflect UV light while they remain transparent (e.g. titanium oxide), a excellent antioxidant properties (e.g. C60 fullerene), antibacterial properties (e.g. nanosilver), and anti-aging skin properties (e.g. nanosomes and gold particles). On the other hand, the increased usage of cosmetics will introduce waste streams containing ENMs directly to the aquatic environments (bathing, swimming) or indirectly (sewage systems). This is because of the high concentrations of ENMs in cosmetic products in comparison to other nanoproducts [6]. Also, according to Mueller and Nowack [10] 95% of these nanoscale materials are most likely to end up in water treatment plants. Such data points to potential adverse impacts of nanowaste streams in the environment.

Currently, it has been assumed that the existing waste management technologies have the capability to remove ENMs, but, there are no data available to validate that as this largely remains unknown. Results of Leppard et al. [11] showed that standard wastewater treatment poorly removed ENMs from effluents, nanoparticles being detected in discharges from wastewater treatment plants. The laboratory-scale findings of Westerhoff et al. [12] illustrated the wastewater treatment system inability to remove ENMs from drinking water (low removal efficiencies ranging between 0 and 40%). This implies their potential presence in drinking water, and may pose an exposure pathway to humans [12]. Zhang et al. [13] investigated the dispersion and stability of metal oxide NMs in water as well as their removal through use of potable water treatment processes. The findings showed that after 24 h of fast aggregation, nanoparticles did not settle out of water efficiently, for example, 20–60% of the initial concentration of 10 mg/l still remained in the settled water. In an aqueous environment containing small concentrations of electrolytes, nanoparticles may be present for a relatively longer time even if they are in an aggregated state [13]. Limbach et al. [14] showed that a significant fraction of the NMs escaped the wastewater plant's clearing system, and up to 6 wt.% of the model compound cerium oxide (CeO_2) was found in the waste stream. This means that current water facilities may face the challenge of removing ENMs as the quantities increases in the future. These findings are important for developing water treatment technologies to remove them from drinking water as well as the effluents. Because research on the efficacy of removing ENMs from wastewater systems has just begun, it is early to draw conclusions on the efficacy of the current waste management systems suitability of dealing with new nanoscale pollutants. As a result, ENMs are likely to pose new challenges to the current waste treatment technologies. One of the problems is reducing waste treatment operational efficacies due to the surface coatings of ENMs.

Also, the use of landfills as a waste disposal is expected to continue into the future and it is likely that products containing ENMs will be placed in landfills at the end of their useful life. This hypothesis has been justified by recent life cycle analyses that suggest over 50% of ENMs produced (worldwide yearly production of 350, 500, and 5000 tones/yr for nano-Ag, carbon nanotubes (CNTs), and TiO_2, respectively) will eventually habit in landfills [10].

Current knowledge regarding the long term behavior of nanomaterials in landfill is still limited. Release of ENMs incorporated in commercially-available products is probable mostly for those bound in liquid or gel products (i.e., cosmetics, sunscreens, hair products), wastewater biosolids and in waste streams. After release, they could be easily transferred to the leachate stream. Not enough studies have been conducted evaluating the fate of the ENMs released into the leachate, whether they will aggregate in leachate, or diffuse. Landfill conditions change over time and that may influence ENMs behavior and need to be considered. More over, changes in environmental conditions, such as acidification (acid rain) or changes in the redox potential conditions can favorize mobilisation from the solid to the liquid phase and favour the contamination of surrounding groundwaters. Because of that, it is very important to design laboratory scale experiments that can simulate conditions in landfills. Essentially, degree of leaching from waste is defined by leach resistance. Leaching is known to be a complex phenomenon because many factors may influence the release of specific constituents from a waste over a period of time. These factors include major element chemistry, such as pH value, redox potential, complexation, liquid-to-solid ratio, contact time, etc. Since not enough is known about the chemical species present in these waste forms and their behavior over time, the long-term performance of this waste forms is difficult to predict. Also, leachate limit values have not been established with the particular characteristics and potentially increased toxicity of the nanoform in mind.

One of the wide spread applications of ENMs is also the food packaging. Applications of nanotechnology in fact can provide new food packaging materials with improved mechanical, barrier and antimicrobial properties, together with nano-sensors for tracing and monitoring the condition of food during transport and storage. In particular carbon nanomaterials (CNs) have been attracting a great deal of research interest. Also, carbon nanotubes could be printed on PET and paper to produce chemical sensors to detect Cl_2 and NO_2 vapors at sub-ppm concentration levels. These sensors are capable of detecting and differentiating gases and vapors at a ppm concentration level showed the successful implementation of printed CNT-based gas sensors with exceptionally high and immediate sensor response to NH_3 and CO_2. Also, metal nanoparticles such as silver, gold, zinc, or metal oxides have been used in various active packaging applications. Among emerging technologies nanocomposite packages are predicted to make up a significant portion of the food and beverage packaging market in the near future. But we must have in mind that that every designed package eventually ends up as unwanted waste that must be dealt with at some cost. If the recycling is not resolved, such package can end up at landfills.

Conclusion

Technological development has led to the presence in the waste, of new substances that may influence environment. The majority of monitoring programs and waste treatments are currently based on regulated substances. Currently, questions exist about the potential impacts of materials that are new and not regulated. These materials can be detected in the environment but are not yet included in monitoring programs, and their behavior, fate and ecotoxicological effects are not well understood. Studies that mimic environmentally realistic conditions are necessary to elucidate the real effects of ENMs in the environment. Also, these substances are numerous and widespread in wastes, and conventional waste treatments might be not suitable to deal with them.

Acknowledgment.

The authors acknowledge the support of the Provincial secretariat for science and technological development, Autonomous Province of Vojvodina for participating in ES COST 1205 action and the Ministry of Education, Science and Technological Development, Republic of Serbia (Grant No. TR35015).

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